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ABSTRACT

Conditional logic, as interpreted in this paper, means deductive logic characterized by "if-then" statements. This study sought to investigate the knowledge of conditional logic possessed by primary children and to test their readiness to learn such concepts. Ninety students were designated the experimental group and participated in a 15-week program of weekly audio-tutorial lessons in conditional logic. 87 pupils were in a control group. A measure of verbal intelligence, and information about socioeconomic status, and rural, suburban, or urban dwelling areas were collected from both groups. At the end of the 15 weeks, the Smith-Sturgeon Conditional Reasoning Test was administered to both groups to assess the effects of the lessons. There was no significant intergroup difference. Therefore, although the experimental method did not effectively teach conditional logic, many of the children had already mastered it even though they were well below the age of 11 to 12 which Piaget considered necessary for mastery. Conditional logic ability was found to be significantly related to verbal intelligence and socioeconomic status, but not to sex. (MH)

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CONDITIONAL LOGIC AND PRIMARY CHILDREN*

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In an attempt to secure more information about the logical abilities of young children, we in the Cornell Critical Thinking Project studied a wide variety of primary children and asked two basic questions, which we labeled the "readiness" question and the "developmental" question:

1. The readiness question: To what extent are various sorts of primary children ready to learn the basic principles of conditional logic?

2. The developmental question: How much knowledge of conditional logic do various sorts of primary children already have? We call this second question the developmental question because an answer to it would indicate the current state of development of primary children in the area of conditional logic.

The answers to both questions should, we feel, be of interest to teachers, curriculum specialists, textbook writers, programmers, and others because such answers would suggest limits and bases for their efforts to teach critical thinking. I hold, but shall not argue here, that basic competence in deductive logic is necessary for competence in many aspects of critical thinking (see Ennis, 1962). Furthermore, conditional logic is a crucial type of deductive

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logic, and an understanding of conditional relationships is essential to an understanding of the deductive relationship. Since conditional logic is crucial to deductive logic and deductive logic crucial to critical thinking, we have, I believe, been investigating a key feature of critical thinking.

Conditional Logic Defined and Briefly Analyzed

By conditional logic we mean that sort of deductive logic in which a key role is played by conditional statements; that is, statements of the 'if-then' form. The following is a conditional statement:

If the big handle is up, the bell does work.

This conditional statement, together with the assertion that the big handle is up, implies that the bell does work. By noting this I have just illustrated a simple conditional deductive argument. Understanding this sort of argument constitutes what we call the basic understanding of a conditional argument.

If to the original conditional we added instead the assertion that the bell does not work, then it would follow that the big handle is not up. This sort of move we have called contraposition. (We are thus amalgamating what is often called "denying the consequent" with contraposition, since the basic idea of each is similar to the other.)

If to the original conditional we added instead the assertion that the bell does work, it would not necessarily follow that the big handle is up. To think otherwise is to commit the fallacy of conversion.

If to the original conditional we added instead the assertion that the big handle is not up, then it would not necessarily follow that the bell does not work. To think otherwise is to commit what we call the fallacy of inversion.

If to the original conditional we added instead another conditional to the effect that if the light is on, the big handle is up, then it would follow that if the light is on, the bell does work. This follows by the transitivity of conditionals.

I have just illustrated and named the five basic principles of conditional logic with which we were concerned: basic understanding, contraposition, conversion, inversion, and transitivity. I have gone into these distinctions in this brief report because one of the most significant findings in this and in some other studies (Ennis and Paulus, 1965; O'Brien and Shapiro, 1968) is that there are vast differences in mastery of the various principles.

Another significant distinction, a psychological distinction this time, is one between what we call suppositional and factual logic skill. Factual skill is shown by someone reasoning correctly from premises all of which he believes to be true. Suppositional skill is shown by someone reasoning correctly from premises, not all of which he believes to be true. According to Piaget, "the child [under 11-12] cannot reason from premises without believing in them. Or even if he reasons implicitly from assumptions which he makes on his own, he cannot do so from those which are proposed to him." (1928, p. 252) There is some difference between what we call suppositional ability and what Piaget claims children cannot do (even after one swallows his inconsistency in the previous quote), but our test items tested for both his suppositional ability and ours. All of our suppositional items provided assumptions that were proposed to the children, but were not believed. The children were simply asked to suppose a particular premise to be true. For example, they were asked to suppose that the bell does not work and to reason on the basis of that supposition.

The Children We Studied

At each of the first three grade levels ten children were chosen at

random from classes in each of three upper New York State schools, selected on the basis of the type of dwelling area they served: rural, urban, or suburban. The 90 students thus selected constituted the experimental group, to whom we gave instruction in the five basic principles of conditional logic. A similar group from the same schools was selected to become the control group, which totaled 87 students by the end of the year because of dropouts. Total number of students studied was thus 177.

Each student received an individual I.Q. test, the "Wechsler Intelligence Scale for Children", at the beginning of academic 1968-69. Mean I.Q.'s for experimental and control groups were 105 and 108, respectively, with standard deviations of about 14.

The occupation of the head of household of each student was determined and used to enter what is essentially Warner's (1949) socioeconomic index scale for occupations. This scale runs from 1 (high) to 7 (low). Means for our experimental and control groups were 3.5 and 3.6, respectively, with standard deviations of 2.1. Our urban, rural, and suburban students had means of 4.8, 4.1, and 1.7, respectively.

The "Smith-Sturgeon Conditional Reasoning Test"

Desiring to avoid the reading problem, the premise-memorization problem (for those who could not read), and the problem of artificiality, we avoided paper-and-pencil testing, and developed our own individual conditional logic test, which was based upon given conditional relationships among concrete materials which we supplied. For example, there was a model house with the conditional relationship between the big handle and the bell that I cited earlier in exemplifying the principles of conditional logic.

Specified conditional relationships were demonstrated and taught to the child taking the test. An additional supposition or fact was given, and

then he was asked what conclusion, if any, he could draw. For example, in one suppositional contraposition item he was asked the following (after being reminded of the original conditional):

> Pretend that you tried to ring the bell and the bell didn't ring. What are you pretending? [Student answers.]
>
> Would you know anything about the big handle? Would you know if it was up or was not up, or would you say maybe it was up and maybe it wasn't? [Student answers.]
>
> What made you decide that?

Only if the right answer and a good justification were both given would credit be given for an item. There are twenty-four items in the total test, six for each of these four principles: inversion, conversion, contraposition, and transitivity. For each principle there are three suppositional and three factual items. We did not secure a score for basic understanding, but rather used a student's ability to handle the basic understanding to check to see whether he knew what was going on.

Readiness Results

Teaching of conditional logic was done by a tape recording giving instruction in a booth containing a variety of instructional materials, including a variety of interesting objects. Science content was combined with the logic content.

Among classroom teachers and students we found considerable enthusiasm for these instructional devices, which unfortunately turned out to be ineffective in teaching logic. There was no significant difference between experimental and control groups (using t-tests and analysis of covariance holding I.Q. and socio-economic status constant). Primary students are not ready to learn the principles of conditional logic from the set of fifteen weekly programs we employed.

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We might consequently be tempted to abandon efforts to teach logic to primary children if it were not for the developmental results based on an examination of the control data.

Developmental Results

It seems that even though our teaching of the principles was ineffective, many primary students have already mastered some of the basic principles of conditional logic. That is, 40%, 64%, and 62% of our control first, second, and third graders, respectively, demonstrated masteryof contraposition; 13%, 28%, and 45%, respectively, demonstrated mastery of transitivity; and 20%, 43%, and 31%, respectively, demonstrated mastery of inversion. Even some primary students demonstrated mastery of conversion: 3 of the 28 second graders and 2 of the 29 third graders.*

It should be noted that our criterion for mastery is a stiff one. A student must give a correct answer and a good justification for at least five out of six problems in order to be judged to have attained mastery.

On the basis of these results it seems that Piaget's claim that children under 11-12 "cannot yet handle...propositional logic" (Inhelder and Piaget, 1958, p. 1) needs revision, propositional logic having conditional logic as one of its main constituents. Since there are wide differences among the principles, one should talk in terms of the individual principles rather than conditional logic or propositional logic as a whole. It does appear that there is very little mastery of the conversion principle, but many children have mastered the others, especially the basic understanding and contraposition.

Our results also suggest that there must be some way to teach at least four of the five basic principles of conditional logic to children, since so

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*See Tables 1 and 2 for enumerations of students mastering principles and for statistical comparisons among principles.

TABLE 1
MASTERY OF FOUR BASIC PRINCIPLES OF CONDITIONAL LOGIC

		Inversion				Conversion				Contraposition				Transitivity			
		Mastery (5-6)	? (4)	Non-Mastery (2-3)	(0-1)	Mastery (5-6)	? (4)	Non-Mastery (2-3)	(0-1)	Mastery (5-6)	? (4)	Non-Mastery (2-3)	(0-1)	Mastery (5-6)	? (4)	Non-Mastery (2-3)	(0-1)
Grade 1	C N = 30	6	6	7	11	0	7	8	15	12	7	7	4	4	6	9	11
	E N = 30	4	6	8	12	0	5	9	16	12	9	6	3	9	8	6	7
	Combined N = 60	10	12	15	23	0	12	17	31	24	16	13	7	13	14	15	18
Grade 2	C N = 28	12	5	1	10	3	9	4	12	18	8	2	0	8	7	8	5
	E N = 30	5	4	10	11	0	6	7	17	14	7	7	2	14	3	6	7
	Combined N = 58	17	9	11	21	3	15	11	29	32	15	9	2	22	10	14	12
Grade 3	C N = 29	9	6	6	8	2	8	7	12	18	10	1	0	13	5	8	3
	E N = 30	8	10	5	7	2	10	9	9	17	8	4	1	10	7	10	3
	Combined N = 59	17	16	11	15	4	18	16	21	35	18	5	1	23	12	18	6
All Grades Combined	C N = 87	27 (31%)	17 (18%)	43 (51%)		5 (6%)	24 (26%)	58 (68%)		48 (55%)	25 (29%)	14 (16%)		25 (28%)	18 (20%)	44 (51%)	
	E N = 90	17 (19%)	20 (22%)	53 (59%)		2 (2%)	21 (23%)	67 (75%)		43 (48%)	24 (27%)	23 (25%)		33 (37%)	18 (20%)	39 (43%)	
	Total N = 177	44 (25%)	37 (20%)	96 (55%)		7 (4%)	45 (25%)	125 (61%)		91 (51%)	49 (28%)	37 (21%)		58 (33%)	36 (20%)	83 (47%)	

Note: A score of 5 or 6 resulted in classification under mastery; a score of 4 was judged borderline; and a score of 3 or below resulted in classification under non-mastery. See Chapter 4 for explanation of method of obtaining score.

TABLE 2
COMPARISONS OF CONTROL GROUP PART SCORES
N = 87 (d.f. = 86)

	Comparisons	Mean	Difference	t	Superiority Indicated (All differences are significant.)
1.	A. Fallacy Principles	5.06	2.87	6.8	
	B. Validity Principles	7.93			X (Validity Principles)
2.	A. Suppositional Items	6.21	0.68	4.1	
	B. Factual Items	6.89			X (Factual Items)
3.	A. Inversion	3.01	0.97	5.6	X (Inversion
	B. Conversion	2.04			
4.	A. Inversion	3.01	1.60	6.5	
	B. Contraposition	4.61			X (Contraposition)
5.	A. Inversion	3.01	0.29	3.4	
	B. Transitivity	3.30			X (Transitivity)
6.	A. Conversion	2.04	2.57	12.2	
	B. Contraposition	4.61			X (Contraposition)
7.	A. Conversion	2.04	1.26	5.2	
	B. Transitivity	3.30			X (Transitivity)
8.	A. Contraposition	4.61	1.31	6.8	X (Contraposition)
	B. Transitivity	3.30			

Critical Values for Two-Tailed t Tests

Degrees of Freedom	Levels of Significance .05	.01
60	2.00	2.66
120	1.98	2.62

many have already somehow learned these principles. Whether conversion can also be taught to primary children is problematic, since so few showed mastery of it. Admittedly, however, this whole line of thinking is speculative. Someone must find a way to teach the basic principles of conditional logic to primary children before we can say positively that they can be taught.

Although there was a statistically-significant difference between control group means on suppositional and factual items, the size of the difference is not very large practically. Mean score on factual items was 6.89 compared to 6.21 on suppositional items (out of a possible 12 in each case).*

Rather more significant is the fact that the children did so well on the suppositional items.** Of the 87 control children, 34 answered all three suppositional contraposition items correctly, 21 answered all three suppositional transitivity items correctly, 20 answered all three suppositional inversion items correctly, and 5 answered all three suppositional conversion items correctly. I remind you that no credit is given without a correct answer and a good justification. A child who does not know what he is doing will not get half right by chance; he will get none right.

I feel that these facts refute Piaget's claim (quoted earlier) that the child under 11-12 cannot reason from premises which he does not believe and/or which are proposed to him, whichever way you construe his claim.

Other interesting results are the fairly high correlative relationships between conditional logic total scores and verbal I.Q. (.50, .64, and .62 for control grades one, two, and three, respectively); and the medium-sized correlation relationships between conditional logic scores and socioeconomic status (.39, .48, and .46, respectively). Relationships between conditional

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*See Table 2.

**See Table 3.

TABLE 3
COUNTS OF STUDENTS WHO HAD SPECIFIED NUMBERS OF CORRECT ANSWERS
ON SUPPOSITIONAL AND FACTUAL ITEMS

Principle:		Inversion						Conversion						Contraposition						Transitivity					
Number Correct:		3		2		1-0		3		2		1-0		3		2		1-0		3		2		1-0	
Form:		S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Grade 1	C N = 30	4	7	7	10	19	13	0	0	7	10	23	20	8	11	11	12	11	7	3	3	8	13	19	14
	E N = 30	3	3	7	11	20	16	0	0	5	7	25	23	4	11	17	15	9	4	3	8	13	12	14	10
Grade 2	C N = 28	9	12	8	6	11	10	3	3	9	15	16	10	10	20	14	8	4	0	7	6	10	12	11	10
	E N = 30	5	6	3	9	22	15	0	0	7	11	23	19	10	15	8	12	12	3	11	12	7	8	12	10
Grade 3	C N = 29	7	9	9	7	13	13	2	1	8	9	19	19	16	16	12	13	1	0	11	13	9	7	9	9
	E N = 30	5	8	14	12	11	10	1	1	13	13	16	16	14	18	10	9	6	3	9	10	8	10	13	10
Total	C N = 87	20	28	24	23	43	46	5	4	24	34	58	49	34	47	37	33	16	7	21	22	27	32	39	33
	E N = 90	13	17	24	32	53	41	1	1	25	31	64	58	28	44	35	36	27	10	23	30	28	30	39	30

logic scores and dwelling area (with "1" assigned to urban, "2" to rural, and "3" to suburban) were smaller (.19, .26, and .41, respectively). Analysis of covariance comparisons among these dwelling areas, however, showed no significant difference when I.Q. and socioeconomic status were statistically held constant.

Correlations between conditional logic total scores and sex hovered around zero except for the first and second graders in the suburban area, where the boys did better. I see no reason not to attribute this superiority to chance, but think that more investigation would be desirable.

Summary

Many primary children already have mastered some basic principles of conditional logic, but the teaching techniques that we used resulted in no significant improvement. We do not know whether other teaching techniques would succeed, but I suspect so. Of the basic principles directly tested conversion was the hardest, and contraposition the easiest with inversion and transitivity in between. Relationship between conditional logic total scores and other factors were roughly as follows: verbal I.Q., strong; socioeconomic status, medium; dwelling area, medium to weak; and sex, minimal, if any.

Statements about children's knowledge of logic must take many factors into account. The days of sweeping statements should be over.

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